

Thick and Thin Liquid Lithium Targets

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Presented by
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High-power Production-target and Stripper-film Development

- **Risk / Opportunity Matrix**
 - Targets
 - Thin Film Strippers
- **Performance Testing Status**
 - Targets
 - Thin Film Strippers - future
- **Alkali Metal Technical and Safety Issues**
 - Engineering
 - Thermalhydraulics
 - Liquid metal pumps
 - Alkali metal handling
 - Fire protection
 - Waste treatment & disposal
- **Future needs**
 - Targets
 - Thin Film Strippers

Risk / Opportunity Matrix

- ***Windowless liquid lithium prototype testing***

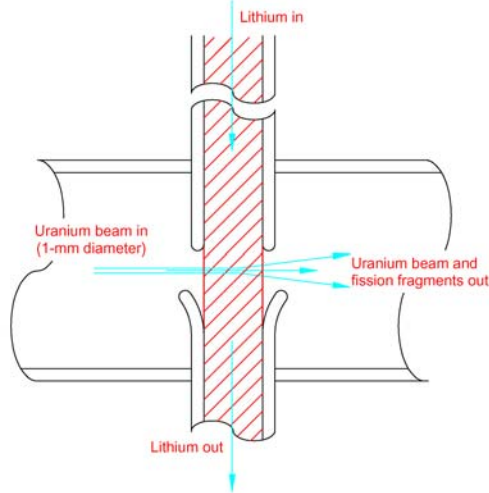
Cost impact:	Medium	High power electron beam demonstration of 1-cm thick liquid lithium jet. In-beam demonstration of target performance (<u>thickness, uniformity and stability</u>). Electron test without heat exchanger by end of FY2003 to meet DOE performance measure. Backup is large rotating graphite wheel; probably power limited to less than 100 kW, which impacts minimum technical baseline power objective.
Technical Impact:	High	
Schedule Impact:	Medium	
Success probability:	High	

- ***Thin liquid lithium stripper films; proof of principle***

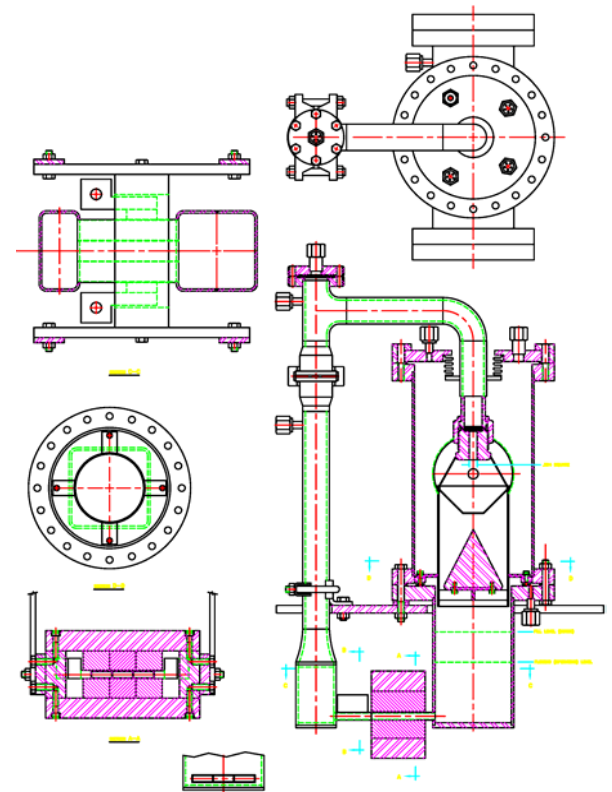
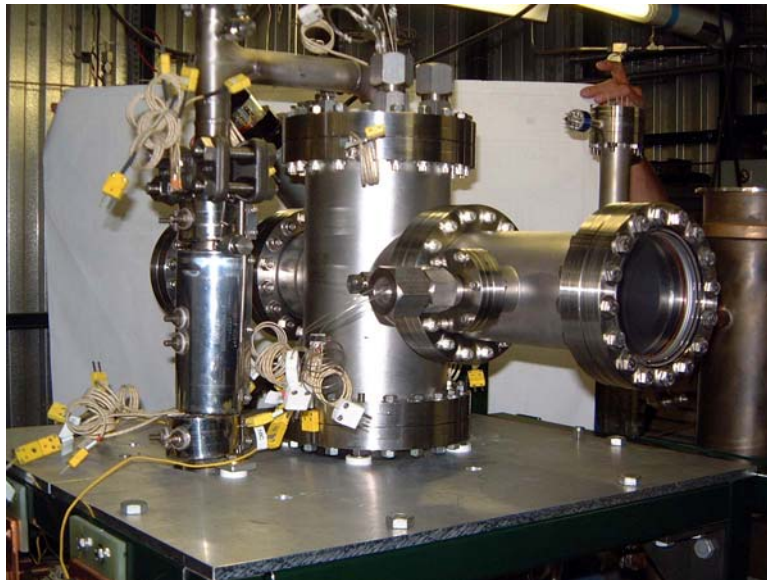
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Technical Impact:	High	
Schedule Impact:	Low	
Success probability:	High	

RIA Windowless Li Target

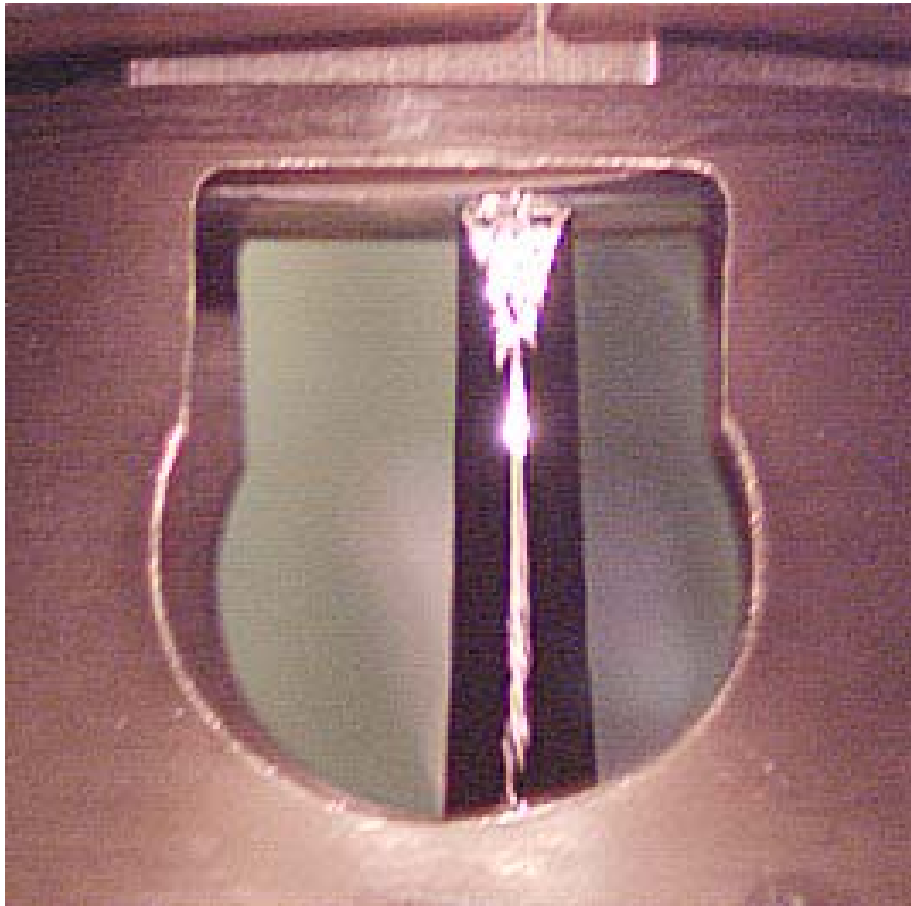
- heavy-ion beams on a low-Z (Li) target



Beam energy:	400 MeV/u
Beam power:	400 kW
Beam diameter:	1 mm
Target thickness:	1.5 g/cm ²



Liquid Lithium Jet



**Temperature rise
across 1 mm dia.
Beam ~ 180 °C**

**5 x 10-mm liquid-lithium jet flowing at 10 m/s in vacuum
(5-mm wide in this view)**

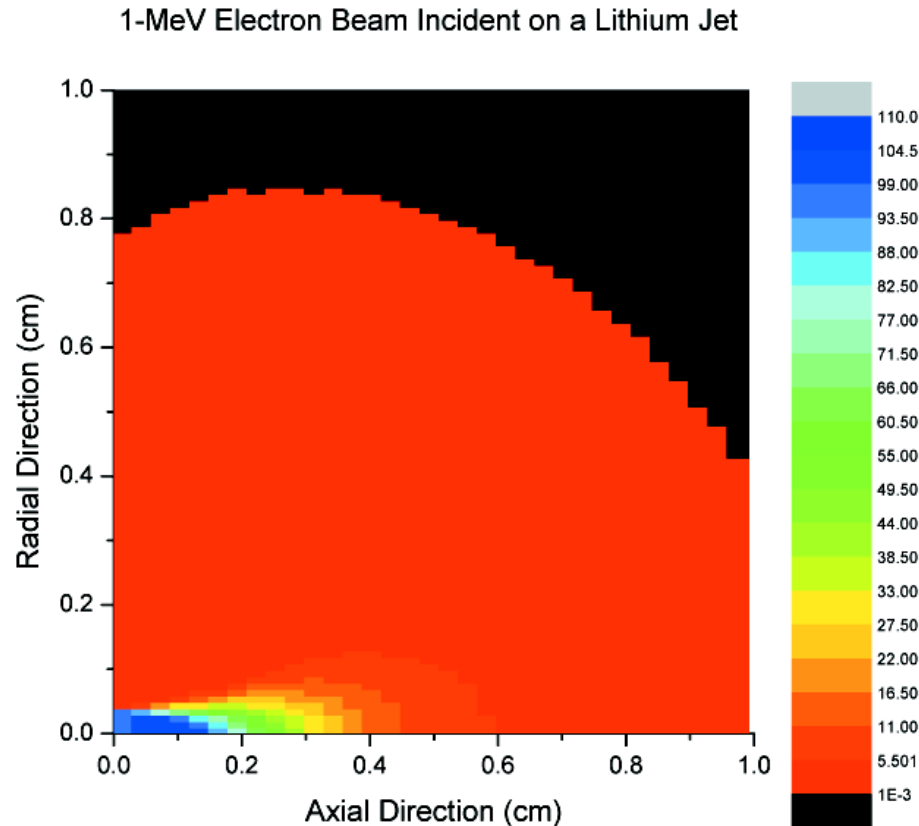
Ultimate vacuum is 10^{-7} Pa or 10^{-9} Torr based on vapor pressure of Li at 200°C₅

The Choice of Liquid Lithium

- **Low Z (=3)---**good from nuclear considerations
- **Large working temp range $\Delta T \sim 1160^\circ\text{C}$**
 - High boiling point (1342°C)
 - Low melting point (181°C)
- **Low vapor pressure (10^{-7} Pa at 200°C)---**only Ga and Sn lower
- **Lowest pumping power required because:**
 - Lowest density (511 kg/m^3)---easiest liquid metal to pump
 - High heat capacity ($4.4 \times 10^3\text{ J/kg-K}$)---highest of liquid metals
 - Low viscosity ($5.4 \times 10^{-4}\text{ Pa-s}$)
- **Low Prandtl No. $\sim 0.05 \Rightarrow$ excellent heat transfer**
- **Applications**
 - Heat Transfer fluid to cool solid targets with light-ion beams
 - Functions as combined coolant and target for high-power heavy-ion beams

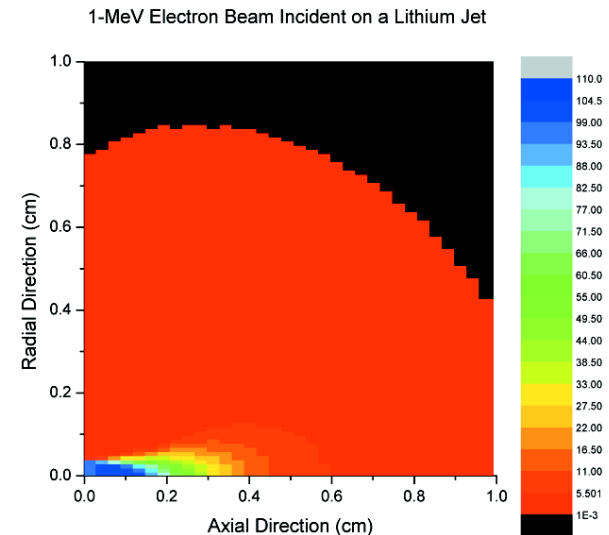
Windowless liquid lithium prototype testing

- **Objective:** to simulate a 300-kW RIA uranium beam, deposited in the first 4 mm of the flowing lithium jet, can be handled by the windowless target



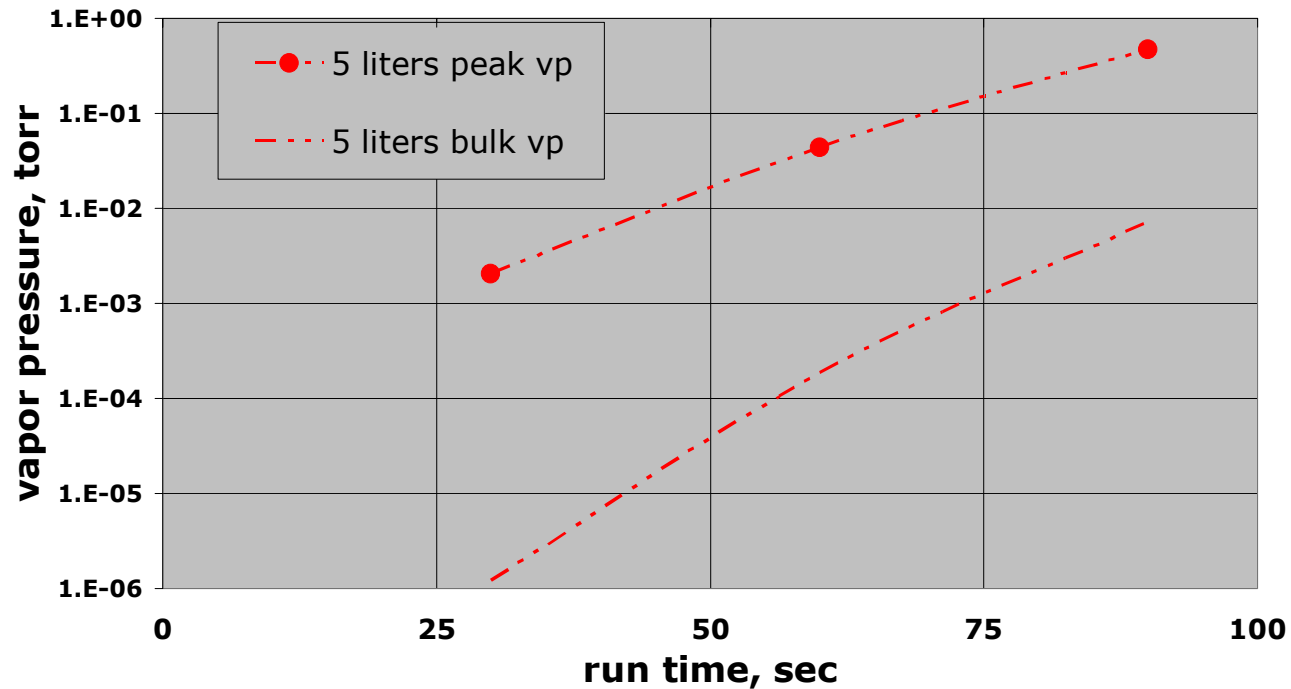
Windowless liquid lithium prototype testing

- **Modified the existing windowless lithium target system to demonstrate its heat removal capability**
- **Completed modifications:**
 - Increased lithium inventory
 - Added EM flowmeter
 - Added pressure transducer
 - Added “portable” heater systems
- **Leased a high power 1 Mev Dynamitron**
 - 1 mm dia. 40 mA beam of 1 Mev electrons
 - 40 kW on target

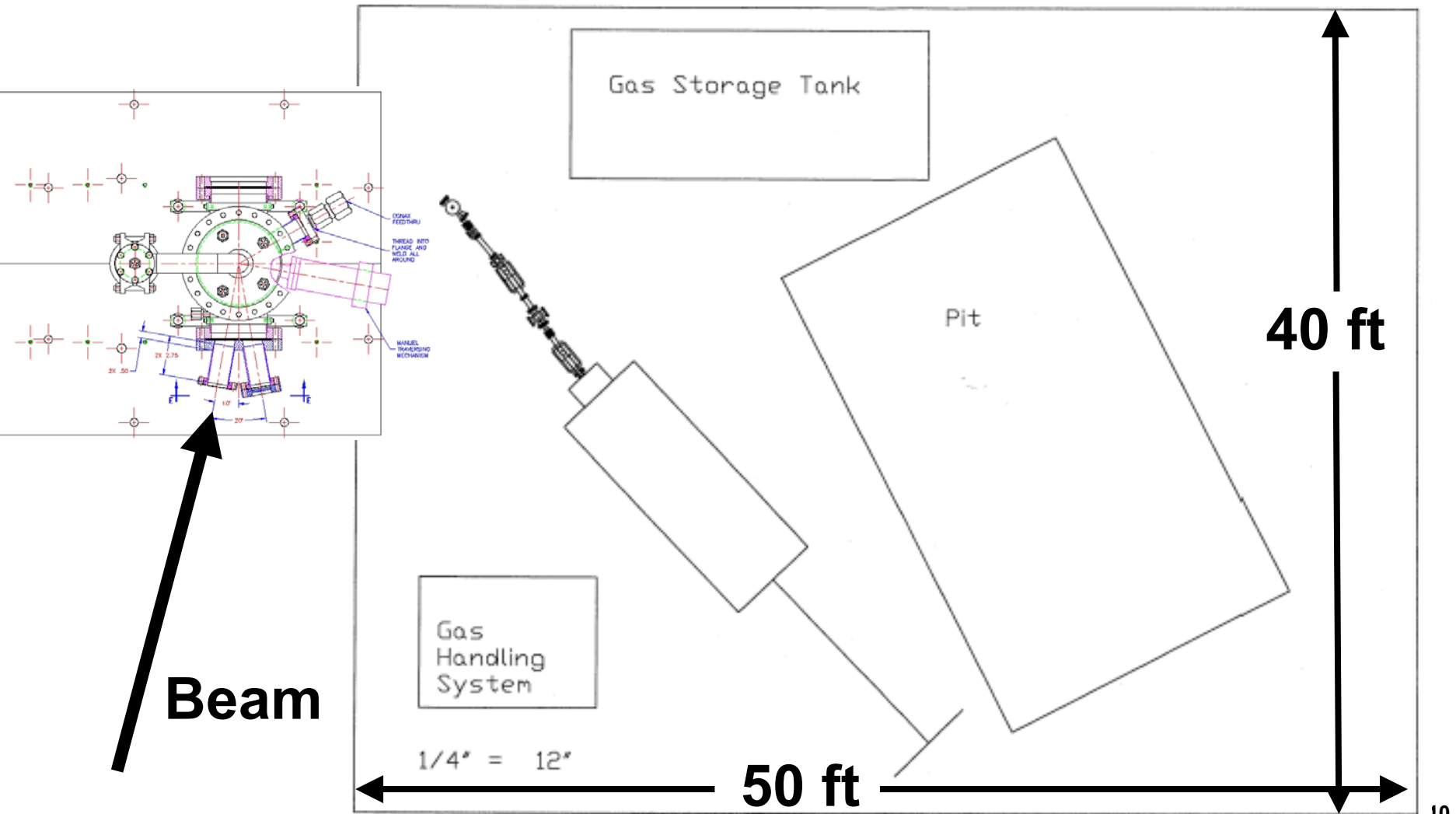


RIA Windowless Li Target

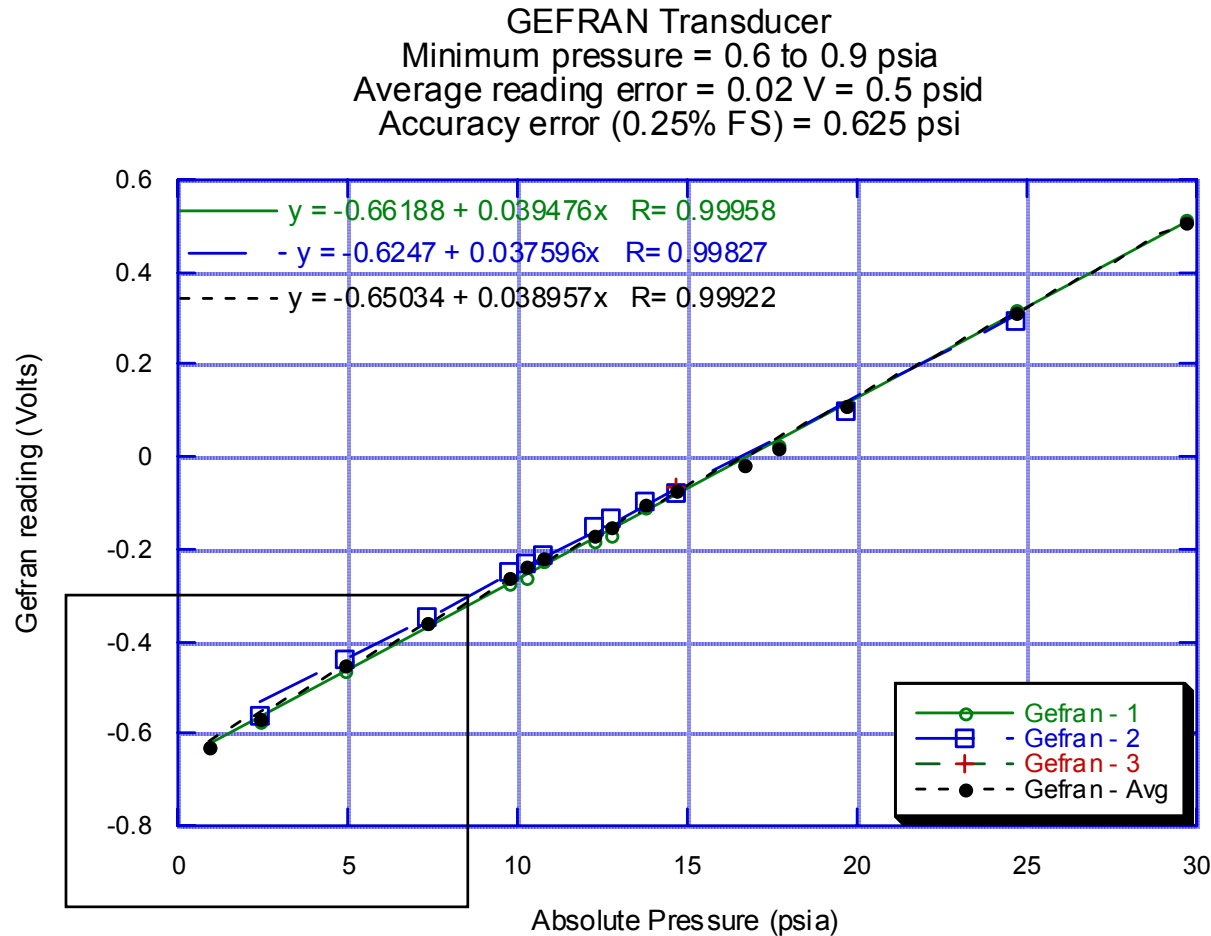
Lithium vapor pressure vs beam on target
run time, 40 kW



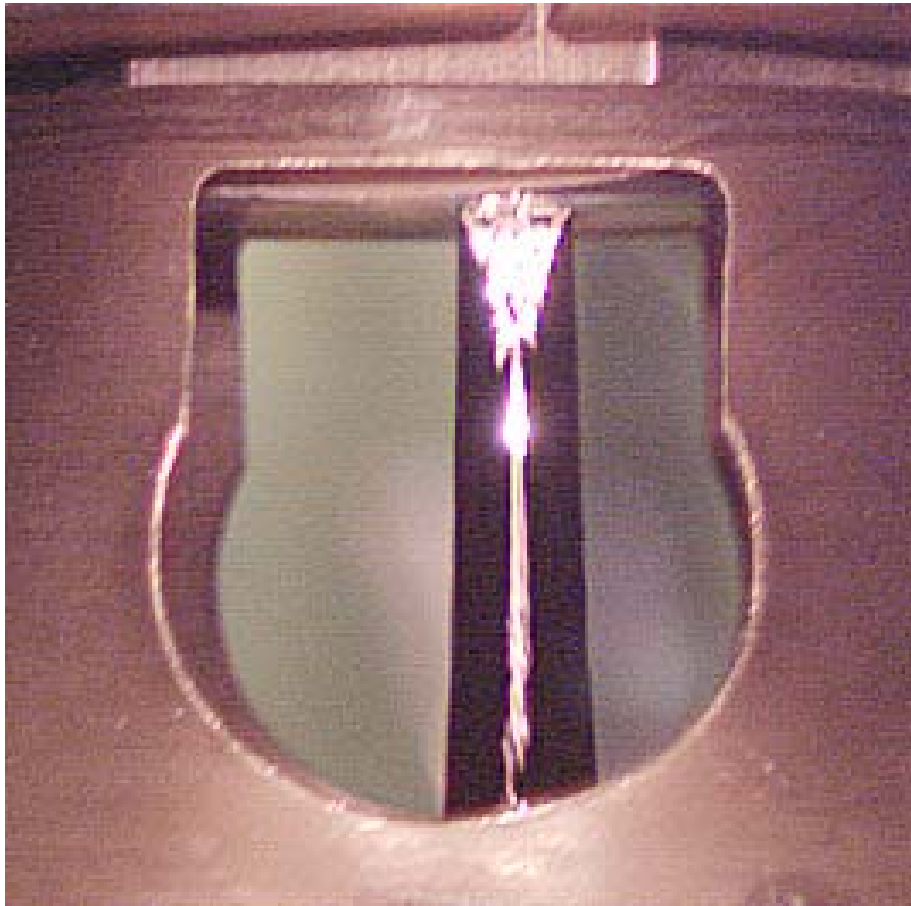
Beam on target floor plan



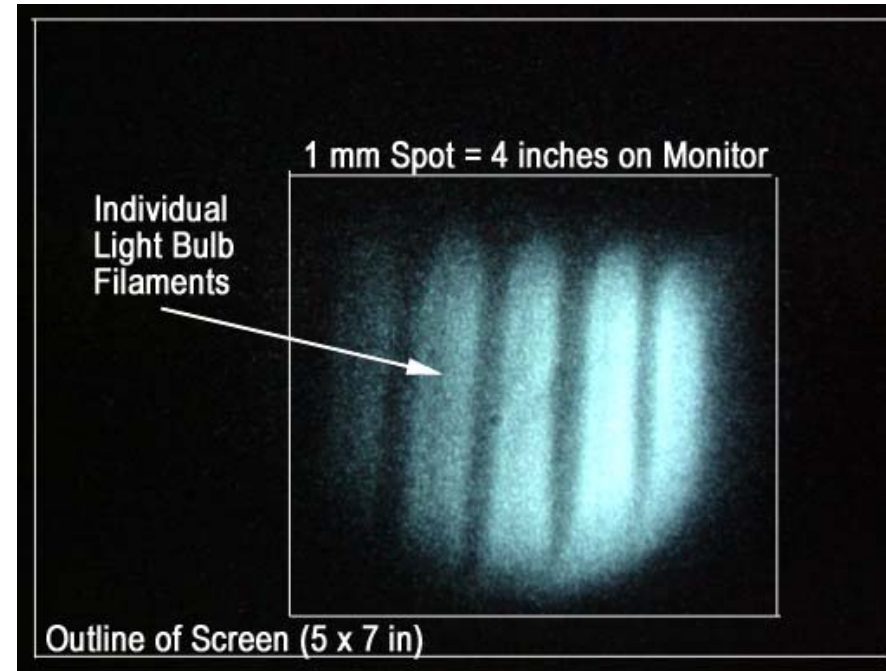
Liquid metal pressure transducer



Liquid Lithium Jet-Beam Spot Image



**Temperature rise
across 1 mm dia.
Beam ~ 180 °C**



Newtonian telescope and CCD camera to view beam spot

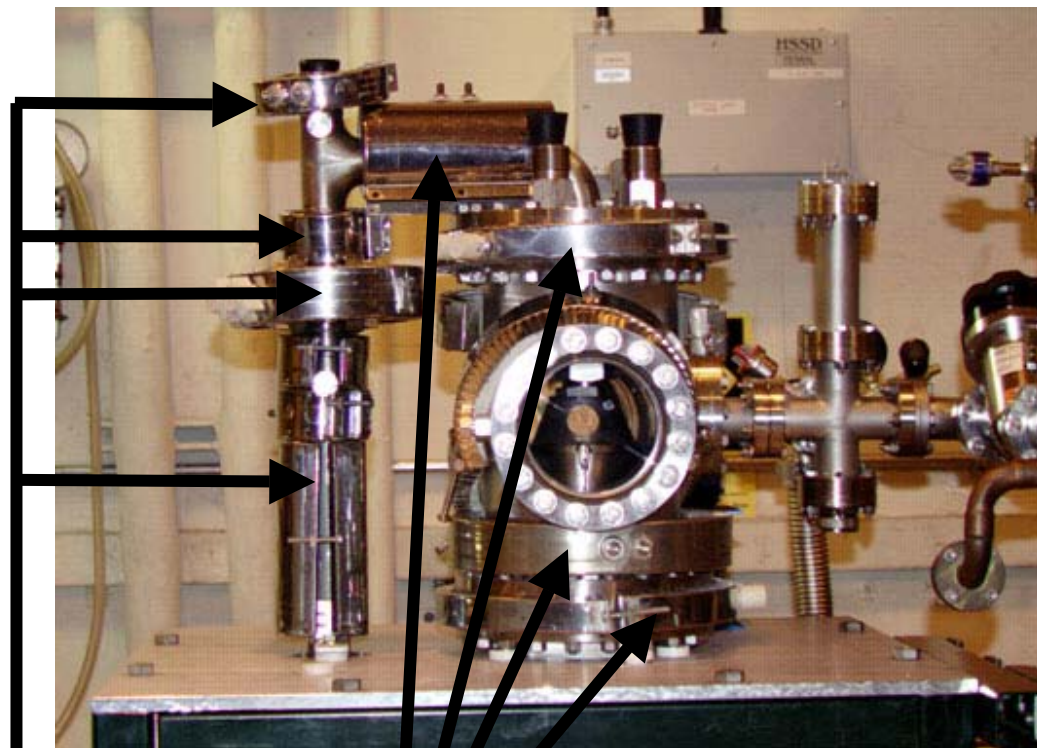
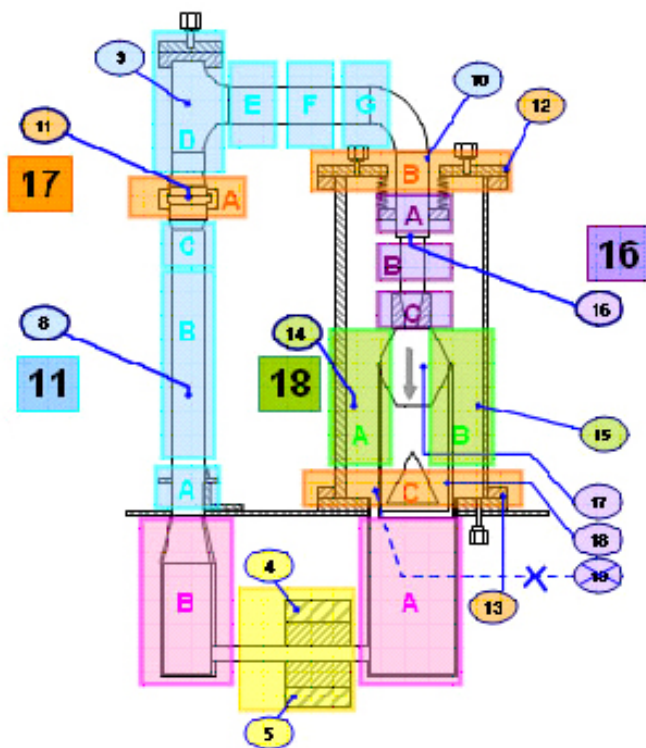
Liquid Metal Engineering Issues

- **Materials of construction**
 - SS, Fe, Ta, Mo, Nb, Be, W
- **Mechanical joint designs, sealing materials**
- Grayloc®, Cajon®, Conflat w/soft iron gaskets, SS o-rings
- **Secondary containment / scrubber**
- **Heating system design**
- **Wetting of EM pumps & flowmeters**

Target & Stripper Heater Systems

- Multiple-zone control system to minimize hot spots

Heater & Recorder Thermocouple Placements:
Windowless Lithium Target Assembly

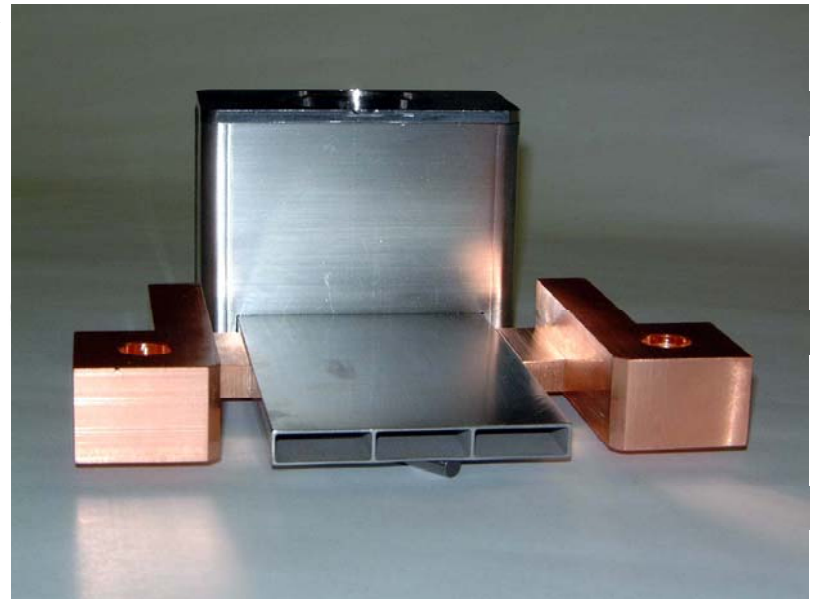
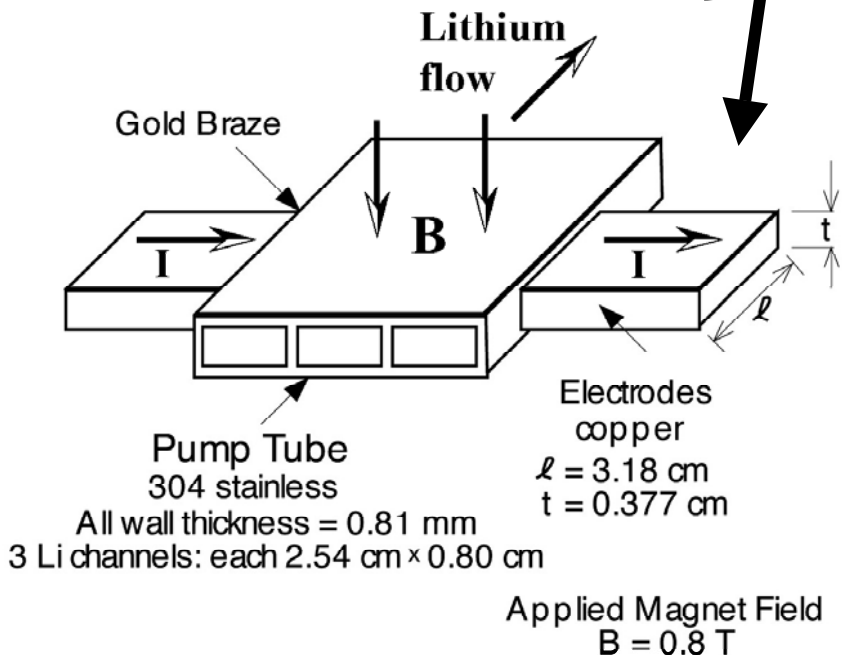
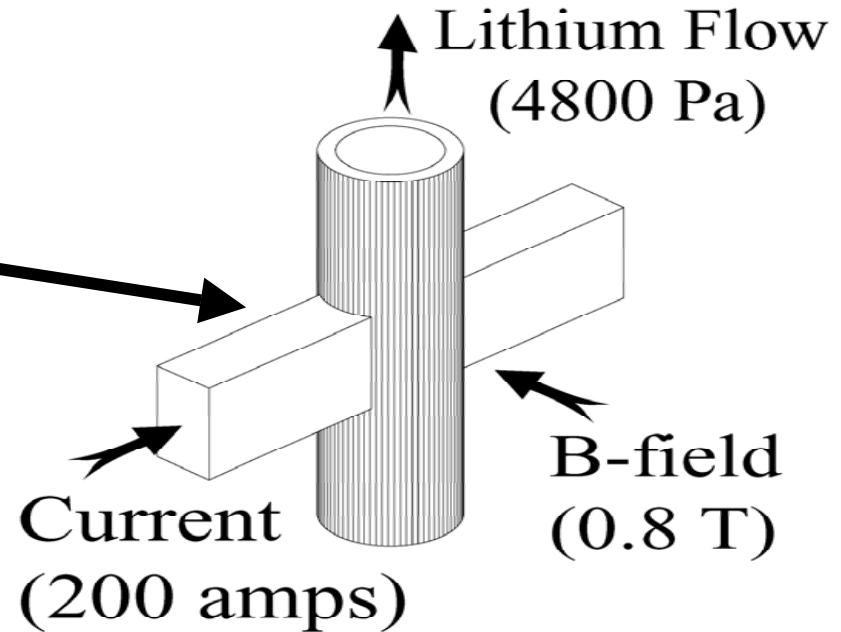


**Ceramic band heaters
provide easy installation**

EM Pumps

- ANL/MSU DC EM pump for adjustable thickness target

- DC EM pump for RIA Windowless target



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- ***Thin liquid lithium stripper films; proof of principle***

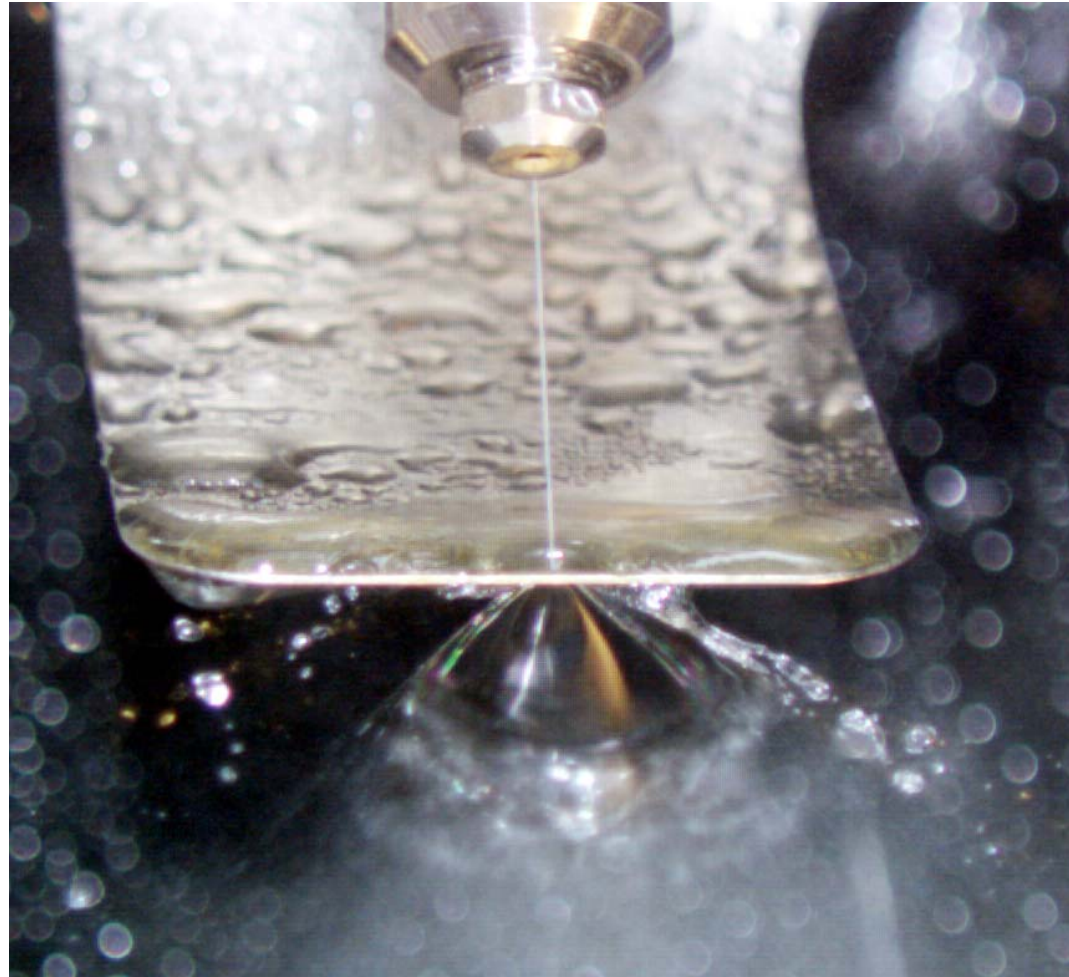
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RIA Thin Film Strippers

- Located within the driver linac
- Increases ion beam charge state

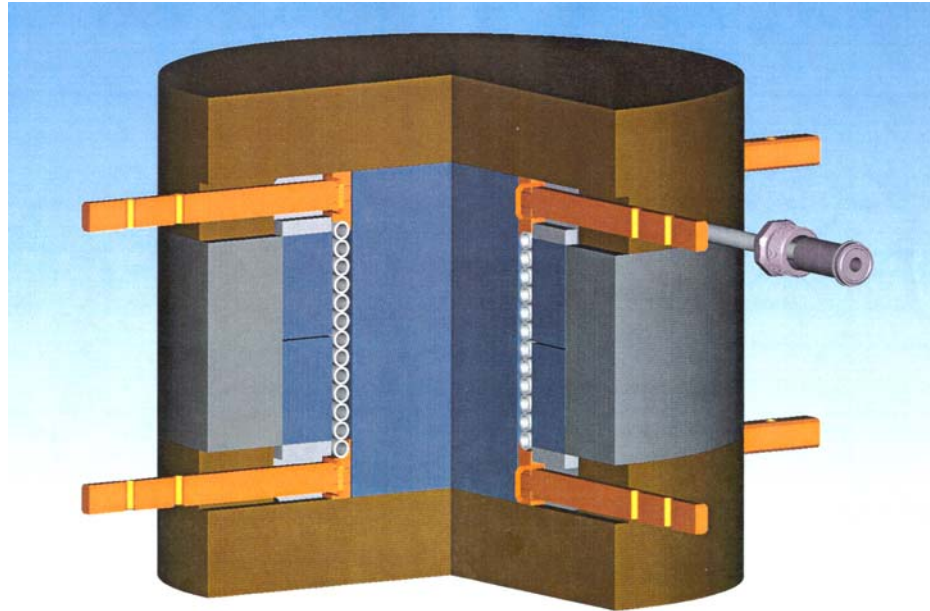
To date:

- Water film
- 0.25 mm diameter orifice
- 33 m/s jet velocity
- 15 atmospheres driving pressure
- >2 micron film thickness
- Under partial vacuum
- Film area ~ 1 cm diameter



RIA Thin Film Stripper Pump Progress

- **RIA Thin Film Stripper Pump Design**
 - DC EM Pump
 - Low flow
 - High discharge pressure



Status

- **Liquid Metal Systems for High Power Accelerators**
 - Targets---Look very promising, 40kW beam on target in 9/03
 - Thin Film Strippers---development underway
- **Technical Issues**
 - Engineering---well understood
 - Thermalhydraulics---well understood
 - Liquid metal pumps ---unique pump required for Li stripper
- **Alkali Metal Safety Issues**
 - Alkali metal handling---well understood
 - Fire protection---well understood
 - Waste treatment & disposal---well understood

Needs for future work

- **Lithium Target**
 - From e-beam tests: collect data for Safety Analysis operating envelope
- **Lithium thin film stripper**
 - High temperature, high pressure pump development [first half of FY2004].
 - Build thin film test stand [first half of FY2004].
 - Film production and stability [second half of FY 2004].
 - Nozzle design and erosion resistance [second half of FY2004].
 - Lithium purification and chemistry control [FY2004].
 - Average film thickness [second half of FY2004].
 - Film thickness variations [FY2005].
 - Lithium velocity distributions [FY2005].
 - Studies of film stability at equivalent uranium beam power density [FY2005].